The Economic Benefits of Crossrail

Prepared in association with

Volterra

October 2007

The Economic Benefits of Crossrail
Final Report

This report has benefited from discussions with staff in Crossrail, the Department for Transport, the Greater London Authority and Transport for London. Responsibility for the analysis and conclusions rest with Colin Buchanan and Volterra Consulting.

Project No: 125721
May 2007

Newcombe House
45 Notting Hill Gate,
London, W11 3PB
Telephone: 020 7309 7000
Fax: 020 7309 0906
Email : London@cbuchanan.co.uk

Prepared by:	Approved by:
A Bhasin	P Buchanan

Status: Final Report Issue no: 1 Date: 05 October 2007

i:\12572x_xr agglomeration research\study\reports\report submitted\may 2007\12572 final xr agglomeration report 09 05 07.doc

Contents

Tables

Figures

Page

Summary

Background

This report summarises the latest work undertaken by Colin Buchanan and Volterra Consulting on the economic benefits of Crossrail. In 2002 the economic appraisal concentrated only on the direct transportation effects, in the form of changes to time and comfort for travellers, which were assumed to capture the whole of the economic benefits. Colin Buchanan and Volterra extended that analysis of economic benefits by developing an approach which quantified and valued the impact of Crossrail on central London growth and productivity by applying the theory of agglomeration.

That work suggested that the economic impacts of Crossrail on business productivity valued in this way were both very large and entirely additional to the transportation impacts.

Clearly this was a radical conclusion and contrary to the conventional approach to transport appraisal. Now five years on, following lengthy discussions and detailed further analysis, the Department for Transport have adopted the approach, and written it up within their own guidance note. The implications are that the UK has been underinvesting, in urban rail infrastructure in particular, by ignoring the wider economic benefits.

The New Results

At the outset, gaining acceptance for such a radical approach led us to produce work on Crossrail which was highly conservative, with a number of restrictive assumptions applied in order to “be on the safe side”. The main report examines the impact on the economic benefits of unpicking some of those assumptions and shows the potential range of the wider economic benefits.

This report explores the following key issues:

- Longer term employment growth paths for London
- Valuation of regional output per head

It also flexes key assumptions in the following way:

- It allows a proportion of jobs to be filled by international migrants
- It removed caps on the growth in output for relocated jobs
- It moves to using the latest agglomeration elasticities published by the DfT

In order to explore their combined effect three scenarios are defined, and the results compared with those from the February 2005 valuation.

The full valuation table is given in Table S1, showing both the direct impacts on GDP and the welfare benefits. Welfare benefits are those normally included in a transport evaluation and are intended to reflect non monetary as well as monetary improvements.

Table S 1: Summary Results: User and Wider Economic Benefits, 60 year PV, £ billions

Benefits	High Scenario		Mid Scenario		Low Scenario		Feb 2005	
	Welfare (£bn)	GDP (£bn)	Welfare (£bn)	GDP (£bn)	Welfare (£bn)	GDP (£bn)	Welfare (£bn)	GDP (£bn)
Conventional User Benefits	**12.8**	**4.8**	**12.8**	**4.8**	**12.8**	**4.8**	**12.8**	**4.8**
Labour force participation		0.9		0.9		0.9		0.9
Move to more productive jobs		46.2		29.9		19.6		7.8
Pure agglomeration	9.3	14.3	8.2	12.6	6.8	10.4	3.8	5.8
Imperfect competition	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Tax Implications	19.2		13.7		9.9		4.7	
Wider Economic Benefits	**29.0**	**61.9**	**22.4**	43.9	**17.1**	**31.4**	**9.0**	**15.0**
Total (User and WEBs)	**41.9**	**66.7**	**35.3**	**48.7**	**29.9**	**36.2**	**21.8**	**19.8**

The differences between the scenarios are substantial, increasing GDP benefits from £19.8bn in the February 2005 valuation to £66.7bn in the high scenario. As a minimum it suggests that there is a very large upside; in our view it shows that the earlier valuation is not a central case but a very conservative valuation.

The table also describes tax implications from the Wider Economic Benefits. This tax take is based around some additionality assumptions and is itself conservative. The transport appraisal of Crossrail includes a loss of tax revenues from fuel tax and VAT, but this analysis suggests that the increase in taxes from the growth in output is far more significant. How the proceeds of that increase in output are divided between returns on capital, labour and property are uncertain and likely to vary over time, but the proportion accruing to government is relatively stable and predictable. This analysis suggests that over the long term investment in Crossrail would generate a positive financial return for government.

Conclusions

The Wider Economic Benefits derived from Crossrail could be worth several times more than the transport user benefits. The DfT's adoption of agglomeration benefits is a major step forward, but the guidance so far suggested represents a cautious interpretation of the potential benefits.

1. Introduction

1.1 Purpose of this document

1.1.1 A large body of work has been created which examines the economic benefits of Crossrail. This has included the development of ground breaking new approaches to valuing the agglomeration benefits of Crossrail, which have since been incorporated into Department for Transport (DfT) appraisal guidelines under the heading 'Wider Economic Benefits'. These are distinct from the transport user benefits, normally described as welfare benefits, which are based on savings of time and discomfort.

1.1.2 The DfT guidance identifies four components of the Wider Economic Benefits:

1. Move to More Productive Jobs
2. Pure Agglomeration
3. Increase in labour force participation
4. Impacts on imperfect competition

1.1.3 The increase in labour force participation and the impacts on imperfect competition (3 and 4 above) are derived directly from the Transport User Benefits. The Move to More Productive Jobs and the Pure Agglomeration benefits (1 and 2 above), which together form the vast majority of the wider economic benefits, need to be quantified and valued separately.

1.1.4 The Move to More Productive Jobs benefits derive from the role of Crossrail in overcoming transport capacity constraints on employment growth within central London. Those benefits reflect the productivity difference between central London and the rest of London. The Pure Agglomeration benefits value the changes in productivity arising from changes to the effective density of employment density. Effective density being the combination of changes to density and to accessibility. The Pure Agglomeration benefits show the benefits accruing to existing jobs.

1.1.5 This report aims to present a complete and up to date picture of the current state of the analysis, explanations of the methods available and the resulting range of assumptions. It also presents the latest overall valuations of Crossrail, for a range of assumptions.

1.2 Overview of the document

1.2.1 The report follows the argument for the benefits of Crossrail.

1.2.2 Chapter 2 starts by setting the scene. London is a premier world city, competing with cities across the globe. Transport improvements should be seen within the context of supporting further success. We present both short term employment forecasts and discuss longer term potential growth paths for London.

1.2.3 Chapter 3 explores methods for understanding the likely impact of the transport constraint on employment growth, and the extent to which this constraint would be relieved by Crossrail. Chapter 4 moves on to a discussion of the output generated by employees in different regions of Britain, and boroughs in London. This includes a new estimate of regional output, which addresses one of the flaws in the current ONS methodology. The ONS methodology is currently under review.

1.2.4 The next stage is to pull together a valuation of the benefits, which is done in Chapter 5. This sets out the methodology for estimating the impact on output for new and existing employees, and for estimating the other components of the 'Wider

Economic Benefits'. The key assumptions are discussed and the effect of relaxing them shown. The changes to the assumptions include:

1. Allowing for international migration to fill some of the new employment opportunities
2. Removing caps on output gains in the Move To More Productive Jobs
3. The DfT's latest published agglomeration elasticities

1.2.5 Chapter 6 pulls together packages of changes to the assumptions, and show their combined effect on the valuation of Crossrail. Chapter 7 describes the tax implications and Chapter 8 the study conclusions.

2. Employment Growth

2.1 Context

London As A Global City

2.1.2 London is a city on the global stage. Its cultural, political and economic influence extends worldwide. West End theatres are located next to global headquarters of multinational corporations, situated down the street from sharp suited financial institutions. In fact, London is matched only by New York as 'well rounded' global city[1], making a considerable international contribution.

2.1.3 The statistics on London's economy are impressive. 19% of the UK's GDP[2] was generated here, US$418 billion in 2005. More US dollars were traded in London than New York in 2005 and more Euros than every other city in Europe combined, overall handling 31% of global currency transactions. Canary Wharf is now home to the global headquarters of HSBC, Reuters, Barclays and many of the largest law firms in the world. Meanwhile the City remains the largest financial and business centre in Europe.

2.1.4 London attracts not only businesses but workers and visitors too, in droves. 300 languages are spoken here, with around one third of residents born outside the UK[3]. The city has been growing rapidly, with 678,000 new residents between 1989 and 2004 and 220,000 new jobs in the same period[4]. This is equivalent to absorbing a city the size of Leeds over that 15 year period.

Competition From Other Cities

2.1.5 While London is in a strong position to continue as a global leader, and to increase and secure employment, this should not be taken for granted. Other major cities are growing and investing in a bid to capture a slice of London's markets. A stunning example of this can be found in the booming new developments in Dubai, but this phenomenon can be found much more widely. Changes in regulations or working practices might also encourage growth to move elsewhere, perhaps with regional centres developing as more important economic or cultural hubs, or other world cities becoming dominant.

2.1.6 A clear example of the issues facing the city is provided by the Financial Services sector. London is currently neck and neck with New York in leading the world in cutting edge financial services. New York has been sufficiently concerned about this that Bloomberg has commissioned McKinsey and Co to investigate how New York can regain its position. However, companies, banks and employees can easily move to other cities if the conditions are favourable. There has therefore been a good deal of research[5] into understanding how these firms choose to locate and what effects policies have on their productivity.

2.1.7 A number of factors are important to CEOs of global companies[6]. These include the regulatory environment, the availability of skilled staff and the quality of life of

[1] Leading World Cities, GaWC, Loughborough University;
[2] London's Place in the UK Economy, 2005-6", p8, Oxford Economic Forecasting on behalf of the Corporation of London, 2002 prices, November 2005
[3] 2001 Census
[4] Midyear Population Estimates ONS, GLA employment estimates – employed and self-employed
[5] "Sustaining New York's and the US's global financial leadership" McKinsay
[6] "Sustaining New York's and the US's global financial leadership" McKinsay

employees. These qualities are often self-reinforcing. The existence of large numbers of educated bankers draws more candidates to the City and helps ensure that they are well trained. Experienced regulators are able to improve the regulation they provide.

2.1.8 Self-reinforcement is one of the mechanisms that have enabled London to remain and develop as a pre-eminent global finance centre, and a reason why it is unlikely to lose this status quickly. However, it is also important to note that self-reinforcing cycles can become self-destructive cycles as circumstances change. Companies moving away would lead to skilled workers moving which would in turn encourage more companies to move.

2.1.9 Large shifts in employment between cities do happen. The Sarbanes Oxley legislation, which was introduced in the US to combat company fraud in the wake of the Enron scandal, has become a big deterrent to companies listing on the New York Stock Exchange as McKinsey's report to Mayor Bloomberg highlights. London has benefited hugely with both the number of public listings and employment growing in response. While financial sector employment fell by over 2000 jobs between 2002 and 2005 in New York, it increased by 13,000 jobs in London.

2.1.10 The introduction of the Sarbanes-Oxley requirements has improved London's position and New York authorities are increasingly concerned about their position. The current experience of New York illustrates how easily a key position can be eroded.

The Importance Of Transport

2.1.11 Overwhelmingly businesses believe that London is a good or very good place to do business compared to other world cities[7] according to the latest report from the Confederation of British Industries. They were divided on London's future with under half expecting London's status as a world city to be further enhanced in five years time.

2.1.12 Transport remains one of their top concerns. A full three quarters of businesses rated transport services as poorer than in other world cities. Two thirds believed more investment in transport was crucial, with the remaining one third stating that it is important.

2.1.13 The strong call from business for improvements in the transport network has been recognised within reports from different government departments.

2.1.14 HM Treasury's 2006 report 'Financial Services in London: Global Opportunities and Challenges', acknowledged the importance of quality of life issues.

"The quality of the living and working environment is a significant factor affecting the location decisions of international financial services firms. According to a 2005 survey on London's competitiveness for the Corporation of London, London ranked behind Paris, almost level with New York, and well ahead of Frankfurt on quality of life measures. London is a dynamic and diverse city, and unquestionably one of the world's most creative capitals. However the Government recognises that there has been historic underinvestment in aspects of the capital's infrastructure and, to help improve quality of life, it is increasing investment in the UK's transport system and tackling a historic UK weakness by addressing longstanding imbalances in the housing market[8]."

[7] Confederation of Business Industry's fourth 'London business survey'
[8] Financial Services in London: Global Opportunities and Challenges: Section 3

2.1.15 This point was also made in the report "Four world cities: a comparative study of London, Paris, New York and Tokyo" which was commissioned by the now Department for Communities and Local Government.

2.1.16 *"Government needs to maintain the right economic climate for business and trade to prosper, and encourage investment in public transport, the environment and flagship facilities and attractions to accommodate and entertain the international businessperson and tourist of the future."*

2.1.17 It should be noted that transport problems do not only impact on the quality of people's daily experience. High levels of demand mean that passengers cannot all physically fit onto trains and tubes. The total level of attainable employment is therefore constrained, and the size of the potential labour market is reduced.

2.1.18 Taken together these factors are serious impediments to the competitiveness of London, and point to the importance of measures that are undertaken to address them.

Employment Forecasts To 2026

2.1.19 The employment forecasts from the GLA show structural growth forecasts for London boroughs. These use historic employment growth to forecast future growth. The forecasts, produced in October 2006, have been incorporated into this analysis. The forecasts for three Central boroughs are demonstrated in Figure 2.1 below.

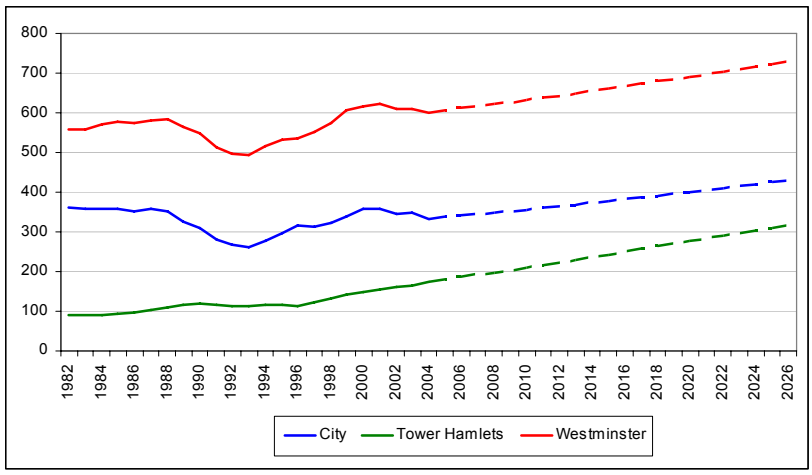


Figure 2.1: GLA Employment Forecasts (000s), for three Central London Boroughs (solid historic, dashed forecast)

2.1.20 Between 2004, the most recent data, and 2026 a total of 367,000 new jobs are forecast in the City of London, Westminster and Tower Hamlets alone. This represents an increase of 33% on current levels. Across the whole of London over 1 million new jobs are forecast, up 22% on 2004 levels. This level of growth clearly presents an enormous opportunity for London, as well as posing considerable challenges for the transport network, especially when existing pressures are taken into account.

Estimating Long Term Employment Growth

2.1.21 Forecasting over long periods requires a view on long term trends and their practicality. It is often the case that the desired forecast period is in excess of the period for which observed data is available which makes it hard to abstract from short term ups and downs. The best estimates rely on historical trends, and then take a judgement on their realism and the extent to which they might change. The

timeframe for most such forecasts is relatively short, much shorter than the timeframes over which benefits from a large infrastructure project are likely to accumulate.

2.1.22 In previous appraisals of Crossrail, employment projections have only been taken to 2026. Earlier calculations used projections specially prepared for Crossrail, more recently they have employed projections prepared for the revision to the London Plan and based on data to 2004, rather than 2000 as in earlier versions. It should be noted that the addition of four years data has not changed the overall trends in growth for London. Up to now, it has been assumed that there is no additional employment growth until the end of the appraisal period in 2076.

2.1.23 These estimations are likely to have been very conservative, since London is likely to grow beyond 2026, with capacity constraints biting even harder past that date. Additionally as Crossrail has been delayed it has come closer to the end of the forecast period, making a longer term view over possible growth paths for London more important.

2.1.24 What might London look like as far forward as 2076? To look at this it is inappropriate simply to extrapolate trends over the existing data available. The data series for employment in London only goes back to 1971, which is a short period over which to extrapolate 60 years. Further, consideration of feasible employment levels is also needed. While there will undoubtedly be cycles in economic growth in this period, it is reasonable to take underlying demand as unconstrained.

2.1.25 This is for several reasons. First, the world economy appears to have entered a period of good growth with the long term entry of large new countries into the world economy. The impact of this will certainly take decades to work through. Second, long term trends are also in favour of cities. Urbanisation across the globe means that more than half the population now lives in cities. If anything, this trend is accelerating. Finally, London is a global city which is competing for a share of world growth. Although it is a very successful city, its share of world city output is still relatively small. Thus, its ability to grow is constrained by its ability to compete rather than underlying demand. In turn, its ability to compete is a function of its infrastructure and other supply side considerations, which at least to some extent are under its own control.

2.1.26 A good way to illustrate London's capacity for growth, especially in its Central Business District, is to compare its structural performance with other world cities. Other world cities provide valuable information since they allow us to view the current 2026 employment projections in terms of what has been achieved elsewhere and to evaluate the scope for further employment growth in this light. This is especially relevant since we know that infrastructure investment has been constrained over a number of years and such an analysis can suggest how growth might have been possible in the central area without such a constraint.

2.1.27 We have therefore explored the possibility of using employment densities from Tokyo, Paris and New York to give an estimate of London's employment potential in the central area.

2.1.28 We first plotted the historical London employment densities and the forecasted densities from the updated London Plan alongside densities in districts in the other cities. The forecasts were then extended forward so that densities approach those elsewhere by 2076.

2.1.29 This analysis gives a useful handle on what a long term future for London might look like. It also provides a useful check on the shorter term London Plan forecasts, which look to be very feasible levels of growth, so long as they are made possible.

2.1.30 Figure 2.2 shows the historical, forecast and comparator densities for the City of London. Historically the City's density has been comparable to the current density for Paris' La Defense business area. In the long term it seems perfectly feasible that the City could reach the density of New York's Downtown CBD. This then provides a cap to the trend growth which might otherwise provide infeasible growth.

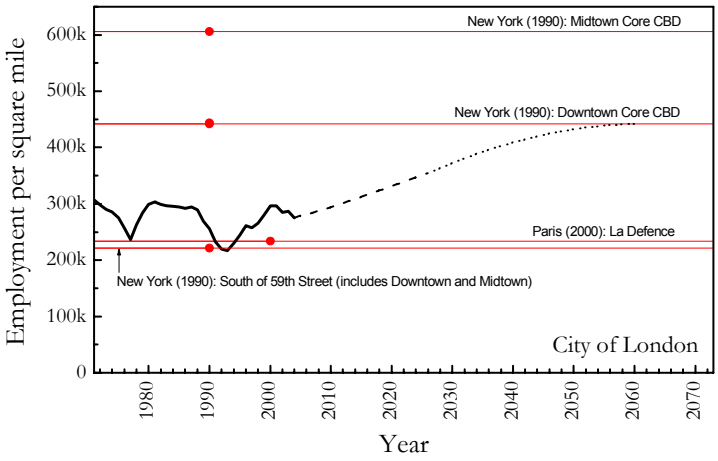


Figure 2.2 Employment density in the City of London, with comparators[9]. Real data (solid), previous forecast to 2026 (dashed) and beyond 2026 (dotted).

2.1.31 Figure 2.3 shows a similar chart for Westminster. Here densities are much lower, and more comparable to Tokyo's Shibuya and Shinjuku districts. We have used Paris CBD to provide a cap on future growth.

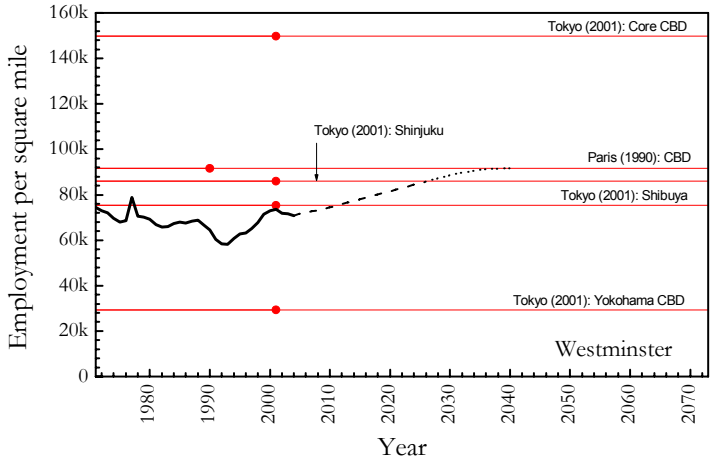


Figure 2.3 Employment density in Westminster, with comparators[10]. Real data (solid), previous forecast to 2026 (dashed) and beyond 2026 (dotted)

2.1.32 Finally Figure 2.4 explores employment densities in Tower Hamlets. Given the phenomenal growth of Canary Wharf and the potential for further significant growth within this borough, the potential employment density increases are much larger. The best cap to trend growth in this case is Westminster .

[9] Sources: Historical employment GLA Economics, World Cities densities Demographia
[10] Ibid

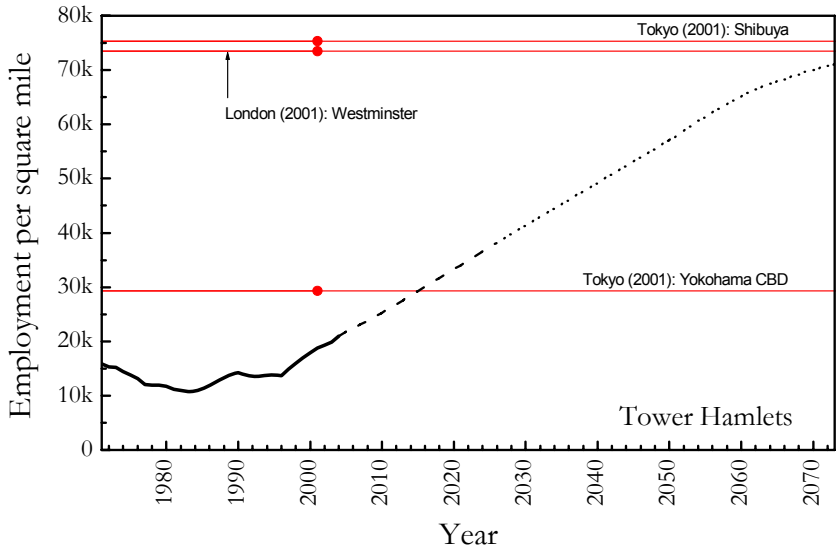


Figure 2.4: Employment density in Tower Hamlets, with comparators[11]. Real data (solid), previous forecast to 2026 (dashed) and beyond 2026 (dotted)

2.1.33 Comparisons with other central business districts have been used to explore the potential for employment growth in central London beyond 2026. Extrapolating trend could be dangerous over such a long time scale, as this might suggest an infeasible growth path. To prevent this, expansion has been capped with reference to comparable parts of other cities, choosing near limits. Even so, continued growth beyond 2026 is still possible, though both the City and Westminster are essentially full by around 2050. Tower Hamlets still has growth potential however. The implications of these calculations for total employment levels are shown in Table 2.1. These long term projections allow us to gauge potential long term growth paths for London.

Table 2.1: Historical and Forecasted Employment in London Boroughs

Area	*1971 (Historical)*	*2001 (Historical)*	*2026 (London Plan)*	*2051 (Projected)*	*2076 (Projected)*
City of London	*370,860*	*358,180*	*429,124*	*525,038*	*534,696*
Westminster	*631,330*	*623,583*	*727,863*	*776,913*	*776,913*
Tower Hamlets	*131,689*	*155,539*	*317,203*	*479,870*	*589,984*
Total	*1,133,879*	*1,137,302*	*1,474,190*	*1,781,821*	*1,901,593*

Source: GLA, Volterra Consulting

2.1.34 Such projections over such a long time frame must be regarded as illustrative of potential. To achieve such potential will require investment on a number of fronts, both in infrastructure and in buildings. However, the existence of such employment levels elsewhere shows that further growth is certainly possible if the right conditions are in place. Crossrail of course will not have the capacity to fulfil all of this growth.

[11] Ibid

But this analysis suggests that it will continue to make a contribution to fulfilling potential beyond 2026.

3. Transport Constraints

3.1 Issues with current modelling

3.1.1 The key benefit of Crossrail is enabling continued employment growth in Central London. Understanding how much employment is enabled requires estimating how many jobs would be deterred from central London with and without Crossrail. Traditional appraisal techniques have struggled to capture this effect.

3.1.2 The transport models focus on forecasting passenger choices of mode and route, thereby to estimate user benefits from transport improvements. These benefits include time savings, cost savings and the benefits of more reliable or frequent services. They also include crowding with higher levels of on-train crowding assumed to add to transport generalised costs.

3.1.3 The models however tend to take total employment and population from projections and these are assumed to be achieved whatever the state of the transport network. In order to do that the models have no capacity constraints on trains (or buses). Thus, even though ail services into central London are already extremely crowded, the models still assume that the forecast increase in commuting to central London can be accommodated.

3.1.4 In order to value the benefit of Crossrail we have therefore had to explore methods for estimating the numbers of jobs which will be lost as passengers are unable, or refuse, to travel on heavily overcrowded lines. This is done in two stages; we first look at estimates for 2016 and 2026, and then develop scenarios for what could happen over the longer term.

3.2 Methods for Estimating Transport Constraint

3.2.1 There have been two methods applied to estimate the number of people who are likely to be crowded out by 2026. These are summarised here and explained in detail below.

1. **Cordon Based**
   Assuming that employment growth within central London is deterred depending on the total level of crowding inbound across the cordon around the central area

2. **Select Link Analysis (SLA) Based**
   Assuming that the percentage of people who are willing to put up with the highest levels of crowding is fixed

3.2.2 A comparison of the key results from these approaches is shown in Table 3.1.

Table 3.1: Summary of results

Method	Jobs Crowded Out		Source
	2016	2026	
Cordon	6,000	33,000	Volterra
Select Link	14,000	26,000	OEF

1. Cordon Based Analysis

3.2.3 This method examined the number of trips crossing a cordon around central London, in the morning peak. It is based on analysis of data on underground lines which showed a relationship between growth in demand for trips, and the initial level of crowding on the line. The more crowded the line, the slower the future growth in demand. Further details are shown in Appendix B.

3.2.4 Crowding is measured as the percentage of planning guidance capacity used (PGC). It ranges from 0 for an empty train, 1 for a train at recommended capacity levels, and beyond that for extreme crowding. The crowding ratios are based on average crowding across the three hour morning peak period, crowding within the peak hour on any individual link will tend to be significantly higher.

3.2.5 We were able to estimate the following simple relationship between average three hour peak period crowding C and the proportion of passengers deterred from making their journey.

$C < 0.65$	No deterrence
$0.65 \leq C < 1.15$	An increasing proportion of people are deterred
$C \geq 1.15$	All deterred

3.2.6 Within this method the forecast growth in employment is converted into a forecast demand growth across the cordon. Every year a proportion of this growth is deterred following the relationship above.

2. Select Link Analysis

3.2.7 The second method examines the average level of crowding experienced by each passenger on route to Central London. The transport modelling provides us with estimates for the percentage of people who experience each level of crowding in their morning commute and the amount of time that they spend under each level.

3.2.8 We then assume that the distribution will remain the same in future. That is, the current proportion of people who are prepared to experience very high levels of crowding will continue into the future, with some of the other people being deterred, and some having their overcrowding relieved by those who are deterred. This assumption reflects the idea that some jobs are more worthwhile to commuters and perhaps harder to locate outside of the centre. These commuters are therefore more likely to continue commuting even if overcrowding is severe.

3.2.9 A full explanation of this methodology is available in Appendix A. This again remains unchanged from previous analysis.

3.2.10 The Select Link Analysis distribution of total passenger minutes in excess of each level of crowding is shown in Table 3.2 below.

Table 3.2: Passenger time in excess of each level of crowding (passenger minutes)

Trips To	> 0.00	SI > 0.3	SI > 0.75	SI > 0.8	SI > 1.0	SI > 1.25	SI > 1.5
Dogs	446,549	429,429	277,750	265,040	152,875	49,495	4,105
City	2,687,311	2,474,912	1,916,269	1,718,380	956,689	357,182	38,384
Central	10,115,539	9,204,902	6,909,497	6,323,561	3,835,590	1,425,767	110,991
Westminster	4,753,719	4,347,259	3,218,763	2,971,295	1,875,030	695,869	48,893
All Zones	19,520,347	14,961,387	10,179,974	9,284,052	5,481,881	2,019,459	156,646

3.2.11 The numbers in Table 3.2 are for all time spent in excess of a particular level of crowding, the actual time spent in each level of crowding in 2001 is shown in Table 3.3.

Table 3.3: Actual time spent in each level of crowding (passenger minutes)

Trips to	0.15	0.525	0.775	0.9	1.125	1.375	1.55	Total
Dogs	17,120	151,679	12,710	112,164	103,380	45,390	4,105	446,549
City	212,399	558,644	197,889	761,690	599,507	318,798	38,384	2,687,311
Central	910,637	2,295,405	585,936	2,487,971	2,409,823	1,314,775	110,991	10,115,539
Westminster	406,460	1,128,497	247,468	1,096,265	1,179,161	646,976	48,893	4,753,719
All Zones	4,558,960	4,781,413	895,922	3,802,171	3,462,422	1,862,812	156,646	19,520,347

3.2.12 A further approach to the quantification issue is under development and involves the consideration of a non-linear crowding curve, or a crowding curve that takes a more realistic view of the impact of capacity constraints on journey comfort and time that that applied within the existing models. That non-linear crowding curve would take account of:

- Observed maximum capacities of rail services;
- The additional costs incurred by passengers not being able to board full trains;
- The much longer routeings that are required to avoid capacity constraints; and,
- Impacts of overcrowding on service speed and station crowding.

3.2.13 This is still under development, in consultation with CLRL and LUL, but it is envisaged that such an approach would provide a more robust analysis of the impact of overcrowding on employment in central London.

3.3 Long Term Employment Growth Scenarios

3.3.1 The unconstrained longer term growth analysis presented in Chapter 2 suggests that growth will not stop in 2026 and that the positive impact of Crossrail on central London employment will continue thereafter. Transport model runs for Crossrail, however, are only available for 2016 and 2026, but a view of the benefits of Crossrail should consider what will happen after this.

3.3.2 Chapter 2 shows that substantial growth is feasible after 2026, but Crossrail can only facilitate a fraction of this, given its own capacity limitations. In order to get a handle on how much growth to expect three scenarios have been developed. The highest scenario sees Crossrail enabling 70,000 morning peak period commuters which would make Crossrail as crowded as the average of all rail lines into central London. The important assumption though is that all this capacity is used to enable

employment growth and not to deliver congestion relief benefits. Other lines in London have seen passenger levels reach capacity very quickly after opening. The Jubilee line extension was full enough to warrant capacity upgrades after just 6 years of operation! The growth in this scenario represents just 10 per cent of the total feasible growth in central London between 2001 and 2076.

3.3.3 Three scenarios are described:

- Low Employment Growth– No growth in central London employment derived from Crossrail post 2026, in line with previous valuations
  - 14,000 jobs by 2016, 26,000 by 2026, no further growth
- Mid Employment Growth – Allows for some increase in Crossrail-enabled employment post 2026
  - 14,000 jobs by 2016, 26,000 by 2026, 40,000 by 2036
- High Employment Growth- assumes that Crossrail morning peak demand is wholly additional to the rest of the network by 2036
  - 14,000 jobs by 2016, 40,000 by 2026, 70,000 by 2036

3.3.4 The impact of allowing for the Low, Mid and High Employment Growth scenarios is given in Table 3.4.

3.3.5 Allowing for modest growth after 2026 adds over £2,800m GDP benefits to the valuation. If Crossrail reaches capacity by 2036, as in the high scenario, GDP benefits would climb by over £10,500m.

Table 3.4: Impact on Benefits from Low, Mid and High Employment Growth Scenario

Benefits	*Low Employment Growth Scenario/Feb 2005 Assessment*		*Mid Employment Growth Scenario*		*High Employment Growth Scenario*	
	Welfare (£m)	***GDP (£m)***	***Welfare (£m)***	***GDP (£m)***	***Welfare (£m)***	***GDP (£m)***
Increase in labour force participation	*-*	*872*		*872*	*-*	*872*
Move to more productive jobs	*-*	*7,798*		*10,428*	*-*	*17,419*
Pure agglomeration	*3,789*	*5,830*	*3,878*	*5,967*	*4,343*	*6,682*
Imperfect competition	*485*	*485*	*485*	*485*	*485*	*485*
Exchequer consequences of increased GDP	*4,729*	*-*	*5,565*	*-*	*7,913*	*-*
Additional to Conventional Appraisal	***9,003***	***14,985***	***9,928***	***17,751***	***12,741***	***25,457***

* All entries are 60 years present values discounted to 2002, in 2002 prices

4. Value of Jobs

4.1 Measuring Regional Output

4.1.1 Chapter 3 describes the impact that Crossrail may have upon total employment in London and the next task is to estimate the added value of these jobs. Value is measured here by output (officially called Gross Value Added (GVA)) per head.

4.1.2 Several issues have been raised with the official measures of total output by sub region published by the Office for National Statistics (ONS). The methodology is currently under review by the Advisory Group for Regional GVA Production to see how they may be improved. The committee is not due to report until 2009.

4.1.3 The ONS figures underestimate Inner London's output in two key ways:

1. The whole of the output from financial services is treated as intermediate consumption which is assumed to occur where the final product is produced. This is known as the FISIM adjustment – standing for Financial Intermediation Services Indirectly Measured. In reality London's financial services are consumed nationwide however the current methodology implies that Central London gains very little output from its global financial services.
2. Headquarters are assumed not to produce output. For non-manufacturing industries a part of the firm's output is reallocated to their headquarters pro rata with earnings. However for manufacturing industries productivity is allocated solely to the factories and production centres of companies.

4.1.4 The impact of these issues is to reduce the share of national output said to be produced in Inner London quite substantially. In consequence the productivity and 'value added' of workers in the capital is underestimated, implying that firms may be better off locating elsewhere. However, the reality of employment distribution is evidence that central locations are worth the additional high costs to firms.

4.1.5 The uprate between total Output (GVA) and earnings in London sub regions implied by the published ONS numbers are shown in Table 4.1 below. The uprate shows the relative return to companies from their investment in employees. The table implies that outer London is a stronger choice for business location.

Table 4.1: Implied Uprate between Earnings and Output from ONS Sub-regional Figures

Region/Sub-region	*Headline GVA (£bn) 2004**	*Total Earnings (£bn) 2004***	*Uprate*
Inner London – West	*79.23*	*61.89*	*1.28*
Inner London – East	*45.02*	*30.02*	*1.50*
Outer London - East and North East	*18.09*	*10.00*	*1.81*
Outer London – South	*17.39*	*9.86*	*1.76*
Outer London - West and North West	*35.37*	*19.48*	*1.82*

* Taken from ONS publication: Regional, sub regional and local gross value added released on 15.12.06

** Using mean gross annual earnings from the Annual Survey of Hours and Earnings (workplace analysis) and employment numbers from the Annual Business Inquiry (employee analysis) for full and part time employees.

4.1.6 In order to start addressing these issues we have prepared a re-estimate of London's output in which financial services contribution is dealt with in a more realistic way. At present we have been unable to develop a sufficiently robust estimate of the number of headquarters to deal with the second issue.

4.2 Regional Output with a Financial Services adjustment

4.2.1 The first step is to estimate the amount of financial services which is provided to final consumers and hence should be added to output as a whole The approach here starts by taking the Bank of England estimates for the split of intermediate consumption (consumption by companies and institutions) and final consumption (consumption by consumers, government and net exports) of financial services. The final consumption component is then allocated nationally by the proportion of population. This assumes that all regions have an equal chance of exporting financial services. This almost certainly still underweights London's contribution, since this is where international institutions are largely based.

4.2.2 The remaining element of financial services is provided to other businesses. The location of this consumption is therefore relevant to how the adjustment is made. At present this is done by assuming that the consumption of financial services is in proportion to its production – in other words it is consumed where it is produced. This seems quite implausible. Many businesses outside London nevertheless use financial services based in London. A more reasonable assumption is to assume that the consumption of financial services is related to where business is located rather than where financial services are located. Hence, it is better to allocate intermediate consumption across regions according to the share that each region has of the output of all the non financial services sectors.

4.2.3 This approach is intuitive and provides an estimate which removes part of the inherent bias against Central London which exists in the published figures. We have called this the 'New FISIM adjusted output' and it is shown by London sub-region in Table 4.2 below.

Table 4.2: Uprate between Earnings and New FISIM Adjusted Output

Region/Sub-Region	FISIM Adjusted Headline GVA (£Bn) 2004*	Total Earnings (£Bn) 2004**	Uprate
Inner London – West	94.86	61.89	1.53
Inner London – East	45.21	30.02	1.51
Outer London - East and North East	17.05	10.00	1.71
Outer London – South	17.06	9.86	1.73
Outer London - West and North West	34.04	19.49	1.75

* Calculated from ONS publication: Regional, sub regional and local gross value added released on 15.12.06, Bank of England estimates for the final/intermediate consumption of FISIM and ONS population figures.

** Using mean gross annual earnings from the Annual Survey of Hours and Earnings (workplace analysis) and employment numbers from the Annual Business Inquiry (employee analysis) for full and part time employees.

4.3 Output per Borough per Employee

4.3.1 The regional output values available from ONS are at too large a scale to be of much use in analysing the impacts of Crossrail on agglomeration. It is also not prepared on

a per capita basis. ONS Output is not released at a borough level so it is necessary to estimate the split by borough before applying the Financial Services adjustment.

4.3.2 The share of the total Inner and Outer outputs generated by each borough has been estimated using three different methods. These used the share of total earnings excluding bonuses; total earnings including bonuses and total employment. The first two methods assume that people are paid in proportion to the output they generate, while the third method assumes all people create an equal amount. Information on bonuses is only available for the City of London, Westminster and Enfield, while earnings and employment are available for all boroughs. The total output is then converted into output per head using the GLA employment estimates.

4.3.3 The results from all three methods are presented below. Since the true value of output is likely to lie somewhere between the values estimated by these methods, we have used the average of the results in the calculations.

4.3.4 Previous evaluations have used total 2003 London output split between boroughs using total earnings by borough and GLA employment numbers. The new numbers are therefore both an update to more recent data alongside the change in method. Output per head in three boroughs is shown in Table 4.3 below.

Table 4.3: Output per head, revised from New FISIM adjustment and previously used Insert Table Title

Borough	New FISIM Adjusted Output (2004)				Unadjusted Output (2003)
	A: Using Wages including Bonuses	B: Using wages without Bonuses	C: Using employment	Average of A, B and C	Using wages without bonuses
City of London	98,237	86,427	54,348	79,671	71,708
Tower Hamlets	87,024	93,284	61,204	80,504	60,882
Westminster	60,159	58,051	56,302	58,171	47,648

4.3.5 The total impact of this change on the valuation is shown in Table 4.4. Updating the values for output per head therefore increases Welfare benefits by around £1.2 billion and GDP benefits by over £2 billion. These results do not reflect the alternative employment scenarios described in Chapter 2, but are based on the original figures.

4.3.6 This update is still highly conservative, since it does not address the 'headquarters issue' outlined above.

Table 4.4: Crossrail Welfare and GDP Impacts for Revised Output Values

Benefits	*Revised Output Values*		*Low Employment Growth Scenario/Feb 2005 Assessment*	
	Welfare (£m)	***GDP (£m)***	***Welfare (£m)***	***GDP (£m)***
Increase in labour force participation	*-*	*872*	*-*	*872*
Move to more productive jobs	*-*	*8,953*		*7,798*
Pure agglomeration	*4,354*	*6,698*	*3,789*	*5,830*
Imperfect competition	*485*	*485*	*485*	*485*
Exchequer consequences of increased GDP	*5,379*	*-*	*4,729*	*-*
Additional to Conventional appraisal	***10,217***	***17,007***	***9,003***	***14,985***

* All entries are 60 years present values discounted to 2002, in 2002 prices

5. Valuing the Impact

5.1 Valuing Agglomeration

5.1.1 The previous sections provide the building blocks to understand the additional employment that might be enabled in central London if Crossrail is built, and the difference in output between different regions and boroughs in the UK and central London.

5.1.2 The next stage of the valuation of Crossrail is to bring these results together and estimate the total impact on GDP that would be generated by the scheme. As discussed in the introduction, the components of this are known as the 'Wider Economic Benefits'.

5.1.3 The two largest components of the Wider Economic Benefits are:

1. 'Move to More Productive Jobs' - Calculate the step up in output as people move jobs to Central London
2. Pure Agglomeration – Calculate the increase in productivity of all workers in London as the number of workers increases.

In addition, the other elements are:

3. Increase in labour force participation
4. Impacts on imperfect competition

5.1.4 These steps, and the assumptions which underpin them, are discussed in more detail below.

5.2 Move to More Productive Jobs

5.2.1 This measures the additional output created by the jobs enabled in Central London. This is not as easy as multiplying the number of jobs by the output from each, since these workers would otherwise be able to work elsewhere. If they left a similar job in another part of London or region of the UK only the net gain in output should be counted as a benefit. If they moved from another country, however, their entire output can be counted.

5.2.2 We explore the impact of flexing two of the conservative assumptions included in previous versions of the analysis:

1. The constant employment assumption
2. The 30% cap on gains in output

International Employees

5.2.3 London is a premier world city, and with a large number of international headquarters and cutting edge financial and business services firms. As discussed in more depth earlier in this report, London competes with other global cities for these firms. Crossrail should be seen as an asset to enable London to continue to grow in this role.

5.2.4 Within this framework we clearly expect a sizeable proportion of the enabled employment growth in central London to be from firms which would otherwise relocate internationally. All the additional output from these firms should be counted as benefits for Britain.

5.2.5 Initial work for Crossrail indeed assumed that a proportion of additional central London jobs would be filled with foreign migrants and thus added their total output to the marginal increase in output generated by their British compatriots.

5.2.6 However the DfT recommended that a much more conservative estimate of 'constant employment' within London should be taken. This implies that all the employment enabled in central London is attracted from elsewhere in the city.

5.2.7 This seems unlikely to be the case. Work by OEF for CLRL[12] suggested that on average 17% of any increase in demand for professional and manager level financial and business workers would be filled by inward migration. That does not imply that an equal number of UK residents would become unemployed, more likely the overall amount of employment will increase.

5.2.8 The impact of allowing for increased international migration on the agglomeration benefits is large. If 17% of the additional central London jobs enabled by Crossrail are valued at gross rather than net output then the 'move to more productive jobs' value increases by 22%.

Moving Employment Within London

5.2.9 For those jobs which are indeed relocated within London, a second question arises. Will the additional jobs be as productive as those already located in central London?

5.2.10 The DfT advised that the types of employment enabled by Crossrail would be the same as those that would have located elsewhere. They therefore recommended that gains in output from enabling these employees to move to London should be capped at a 30% increase. This was based on a study of productivity which showed that only 30% of the productivity differential was not explained by workforce qualifications or type of job. This cap has not been included in the DfT's guidance on 'Wider Economic Benefits'.

5.2.11 The cap makes little sense, however, if the jobs enabled in central London are different from the types of jobs found elsewhere. There is good reason to believe this is the case. The types of jobs which are possible in the centre of such a large agglomeration are not possible elsewhere, allowing people to move to different jobs than they would otherwise have.

5.2.12 Again this discussion needs to be viewed within the context of London's continuing growth as a world city. The city is attracting successful companies and industries, employing people who would otherwise work in less high valued employment. Therefore arguing that part of the differential in output is caused by differences in the type of job is right, arguing that that amount should be excluded from the valuation is wrong.

5.2.13 Further, the cap is almost impossible to apply. In order to apply it you must determine where the enabled jobs in central London are moved from, so that the output growth can be calculated and capped. A different value will be applied for jobs which are determined to have been moved from Hillingdon compared to those that have moved from Newham. Clearly there is little analytical rigour in such a process.

5.2.14 Removing the cap increases the valuation of the move to more productive jobs from £8.52 billion to £15.35 billion, an increase of 80%.

[12] OEF International migration equations, November 2004

5.3 Pure Agglomeration

5.3.1 Pure agglomeration is the name given to the growth of productivity of existing workers as the density of employment around them increases. That denser employment leads to higher productivity is a well established idea, while its use in appraisal has been pushed to prominence through the Crossrail studies. Useful discussions are contained in Venables[13] and Graham[14] as well as GLA Economics Working Paper 17.

5.3.2 In essence the higher productivity is achieved through larger labour pools and additional suppliers and clients, which lead to greater competition and the opportunity for specialisation. The effects of it can be seen in the level of innovation in London, and the high prices companies are willing to pay to locate in prime, accessible locations.

5.3.3 In order to evaluate this effect we apply an elasticity of productivity with respect to employment density to the change in employment enabled by Crossrail. There are a number of sources for these elasticities, and issues in their implementation.

Initial Agglomeration Elasticities

5.3.4 In the first evaluations of Crossrail evidence for the magnitude of this elasticity was taken primarily from a literature review by Rosenthal and Strange[15]. They showed evidence from a variety of mostly US studies which found a typical elasticity of average productivity with respect to changes in city size between 0.04 and 0.11.

5.3.5 In July 2005, the first stage research from Dr. Daniel Graham at Imperial College London was published which estimated elasticities for UK industries and local authorities. These were with respect to 'effective density', a measure which counted not only the employment in the specific local authority, but also those nearby. The weighting given to employment in other local authorities depended on the distance they were away and a 'decay rate' parameter.

5.3.6 The data used by in this research came from the 'FAME' dataset, which includes extensive financial information on companies. However the data are not recorded at a plant level so a large number of companies were excluded to create a set which were only operating from one address. The excluded companies included:

1. All firms with more than one trading/registered address
2. All firms with a UK or foreign holding or subsidiary company
3. All firms of more than 100 employees.

5.3.7 In other words the elasticities shown in Grahams work rely on comparison of the output of small, localised firms only. Clearly the firms which locate in the most agglomerated, high value parts of London do not fit this category. The sizes of the elasticities estimated in his work are therefore likely to be very conservative for London.

Latest Agglomeration Elasticities

5.3.8 The DfT have recently published the second stage of research from Dr Daniel Graham[16] . In this work refinements have been made to the methodology, resulting

[13] Venables, A.J. (2004), Evaluating urban transport improvements: cost-benefit analysis in the presence of agglomeration, London School of Economics.
[14] Investigating the link between productivity and agglomeration for UK industries, DfT, 5 December 2006
[15] Rosenthal and Strange 2002, Evidence on the nature and sources of agglomeration economies

in an increase in the size of the elasticities. These results were published by 28 industrial sectors for the UK as a whole.

5.3.9 The main findings from this report include:

- A weighted average urbanisation of 0.129 for the service sector as a whole and 0.07 for manufacturing;
- Diminishing returns set in at some stage for most industries, but not for real estate, retailing, financial services and business and management consultancy for which the elasticities tend to be highest in the most urbanised locations

5.3.10 In previous analysis for CLRL (2002 – 2006) an agglomeration elasticity of 0.07 has been applied. Given this latest report, even the use of 0.125[17] looks conservative given that central London has by far the highest level of agglomeration in the UK and (not surprisingly) is dominated by those sectors which gain the most from agglomeration. The new elasticity represents a 78% increase (0.125/0.07). This results in a 78% increase in the value of the pure agglomeration benefits, from £6.12bn (GDP) to £10.94bn.

5.4 Other Wider Economic Benefits

5.4.1 The justification for including the two remaining steps in the valuation are detailed in the DfT note 'Transport, Wider Economic Benefits, and Impacts on GDP'. These two steps are:

1. Increase in labour force participation; and
2. Impact on imperfect competition.

5.4.2 The method for calculating these benefits are also given in the guidance note, and are straightforward to apply. Details of the transport benefits from which these are derived are given in Chapter 6.

5.4.3 The value of the labour force participation is calculated as 21% of value of the benefits from commuting time savings. It is therefore valued at £862m.

5.4.4 Impact on imperfect competition is calculated as 10% of the benefits from business time savings. The value is therefore £485m

5.5 Completing the Valuation

5.5.1 Once the overall agglomeration benefits of Crossrail have been calculated at one point in time, their total impacts on Welfare and GDP over the scheme time frame must be added up. This requires adding up the benefits in every year until 2076, 60 years after the implementation of the scheme. In order to do this we make standard assumptions on the growth in the productivity of jobs, and the discount rate. The two assumptions that have been used in the analysis are:

- Annual productivity growth at 1.75%
- Annual discount rate at 3.5% to 2046 and then at 3% until 2076.

5.5.2 The results are presented as both an increase in GDP and an increase in welfare benefits. The GDP calculation is the total increase in output, but only part of that

[16] Wider Economic Benefits of Transport Improvements: Link between Agglomeration and Productivity-Stage 2 Report, DfT, 5 December 2006
[17] Wider Economic Benefits of Transport Improvements: Link between Agglomeration and Productivity-Stage 2 Report, DfT, 5 December 2006

increase is allowed as a welfare gain. In general the DfT advise that there is a welfare gain if no changes are required to individual behaviour, but not is individuals change job location or enter the labour force. Thus the Pure Agglomeration benefits all count as welfare benefits but in the case of the Move To More Productive Jobs, only the tax element of the increase in GDP counts as a welfare gain. The taxation issues are discussed further in Chapter 7.

5.6 Summary of Assumptions

5.6.1 The table below gives a summary of the impacts of relaxing each of the assumptions discussed in this chapter in turn. Headline GDP benefits are given in Figure 5.1 below.

Table 5.1: Crossrail Sensitivities

Benefits	Remove Capping		Update Elasticities		Allow for International Migration		Low Employment Growth Scenario/Feb 2005 Assessment	
	Welfare (£m)	GDP (£m)	Welfare (£m)	GDP (£m)	Welfare (£m)	GDP (£m)	Welfare (£m)	GDP (£m)
Conventional user benefits	12,832	4,847	12,832	4,847	12,832	4,847	12,832	4,847
Additional to conventional appraisal	11,188	22,268	13,583	19,565	10,737	20,766	9,003	14,985
Total (user and WEBs)	24,020	27,115	26,415	24,412	23,569	25,613	21,835	19,832

* All entries are 60 years present values discounted to 2002, in 2002 prices

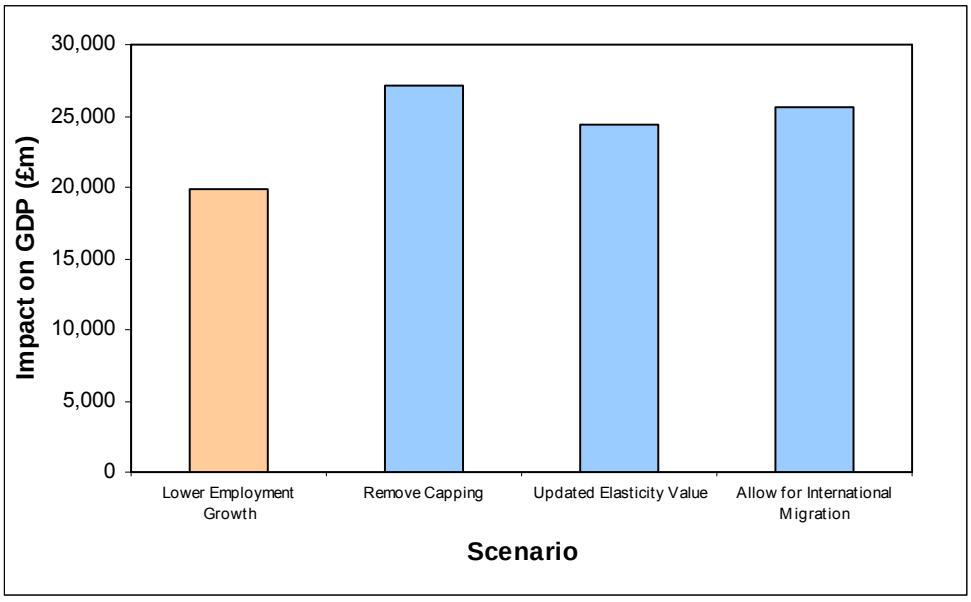


Figure 5.1: Impact of flexing individual assumptions on GDP

6. Crossrail's Total Impact On GDP

6.1.1 This section sets out a range of Crossrail impacts on Welfare benefits and GDP. Three scenarios (Low, Mid and High) have been developed to show the likely range of the economic benefits. In this chapter the benefits comprise both the wider economic benefits, described to date, and the transport user benefits.

6.1.2 The transport user benefits are divided by journey purpose between: trips in work time, commuting trips and leisure trips. All three journey purposes are assumed to deliver welfare benefits but only benefits to trips in work time are assumed to increase GDP.

6.1.3 The Low scenario incorporates only those changes which seem least controversial:

- 17% International Migration
- No cap on output growth; and
- Updated Agglomeration Elasticity.

6.1.4 The mid scenario adds the following changes over and above the Low scenario:

- Revised output per employee
- Updated employment (2016- 14k, 2026-26k, 2036- 40K)

6.1.5 The high scenario then adds the impact of assuming that the number of central London jobs dependent on Crossrail rises to 70,000 by 2026:

- Updated employment (2016- 14k, 2026-40k, 2036- 70K)

6.1.6 The results of both the scenarios are summarised in Table 6.1 below. It can be seen that the forecast scheme impacts on GDP have a wide range. That is in itself a more realistic assumption than the single values which have generally been reported before. Equally interesting is that this range seems to be much higher than the previously reported values.

Table 6.1: Crossrail Impact on Welfare and GDP Insert Table Title

Benefits	High Scenario		Mid Scenario		Low Scenario	
	Welfare (£m)	GDP (£m)	Welfare (£m)	GDP (£m)	Welfare (£m)	GDP (£m)
Business time savings	4,847	4,847	4,847	4,847	4,847	4,847
Commuting time savings	4,152		4,152		4,152	
Leisure time savings	3,833		3,833		3,833	
Conventional User Benefits	**12,832**	**4,847**	**12,832**	**4,847**	**12,832**	**4,847**
Increase in labour force participation		872		872		872
Move to more productive jobs*		46,165		29,919		19,625
Pure agglomeration*	9,322	14,341	8,204	12,622	6,767	10,410
Imperfect competition	485	485	485	485	485	485
Exchequer consequences of increased GDP	19,218		13,742		9,880	
Additional to conventional appraisal (Wider Economic Benefits)	**29,024**	**61,862**	**22,431**	**43,898**	**17,131**	**31,392**
Total (User and WEBs)	**41,856**	**66,709**	**35,263**	**48,745**	**29,963**	**36,239**

* All entries are 60 years present values discounted to 2002, in 2002 prices

7. Tax Implications

7.1.1 The analysis to date has concentrated on valuing the increase in GDP produced by the implementation of Crossrail. It has not discussed how that increase in GDP is divided between profits, wages, rents and taxes. The split between profits, wages and rents will vary over time, but the proportion accruing to government through the tax system is likely to be relatively constant and predictable.

7.1.2 The DfT have provided tax take assumptions for each of the different elements of the Wider Economic Benefits. These are set out in Table 7.1below.

Table 7.1: DfT Guidance on Tax Take

Wider Economic Benefit	Tax Take
Labour Force Participation	40%
Pure Agglomeration	35%
Move to More Productive Jobs	30%
Imperfect Competition	30%

7.1.3 The tax assumptions are given in the guidance without much description or explanation. It seems to us that the marginal tax take for additional employees moving into central London is likely to be considerably higher than 30% (Move to More productive Jobs) or 35% (Pure Agglomeration). Again the assumptions seem conservative.

7.1.4 Table 7.2 shows that there are expected to be very significant increases in tax revenues accruing to government as a result of the wider economic benefits of Crossrail. These do not address the initial financial constraints as they accrue

Table 7.2: Crossrail Impact on Tax Revenues

Welfare Benefits	High Scenario	Mid Scenario	Low Scenario
Exchequer consequences of increased GDP (£m NPV)	19,218	13,742	9,880

* All entries are 60 years present values discounted to 2002, in 2002 prices

7.1.5 The latest scheme estimate for Crossrail is measured at £9bn. It could therefore be seen that the revenues generated e.g. for Low Scenario from exchequer consequences alone for Crossrail are more than sufficient to offset the public sector costs of implementing the scheme, thereby making cross rail a very good value for money scheme.

8. Conclusions

8.1.1 Three main conclusions that arise from the work described within this report:

1. The Wider Economic Benefits are of critical importance in understanding the case for Crossrail
2. The increase in GDP that would be derived from the implementation of Crossrail suggests that such an investment could be financially viable, in terms of 60 year Present Values
3. There remain uncertainties over the valuation of these benefits which are reflected in the relatively large range.

Wider Economic Benefits

8.1.2 Even in the Low scenario the value of the welfare element of the wider economic benefits is significantly higher than the transport benefits. This is not surprising, Crossrail is addressing a capacity constraint affecting the most productive sector of the UK economy, the benefits from relieving that constraint cannot be measured simply from measuring changes in travel times.

GDP Growth And Scheme Funding

8.1.3 The GDP growth predicted is important mainly in that it suggests a real financial return to government. The DfT's guidance on Wider Economic Benefits doesn't address the issue of how to treat future tax revenues to government. That is surprising given the treatment of changes to fuel tax and VAT income which suggest that any reductions in those should be treated as additional scheme costs.

8.1.4 If the increase in tax revenues derived from Crossrail were treated as negative costs then the scheme would be a financially viable investment for government, in terms of 60 year Present Values.

Scale Of Agglomeration Benefits

8.1.5 Each of the three scenarios described within this report represent a large increase on the values previously produced. There are a number of reasons for that:

- Changes to the DfT guidance, specifically the agglomeration elasticities to be applied;
- Our review of the approach and the impact of removing some of the earlier assumptions regarding capping and international migration
- A more realistic approach to the long term impacts of Crossrail on central London employment (and agglomeration)

8.1.6 The latest results suggest a realistic range for the agglomeration benefits from Crossrail of £36bn to £67bn PV over 60 years. However, a complete range of GDP benefits including sensitivities is shown in Figure 8.1.

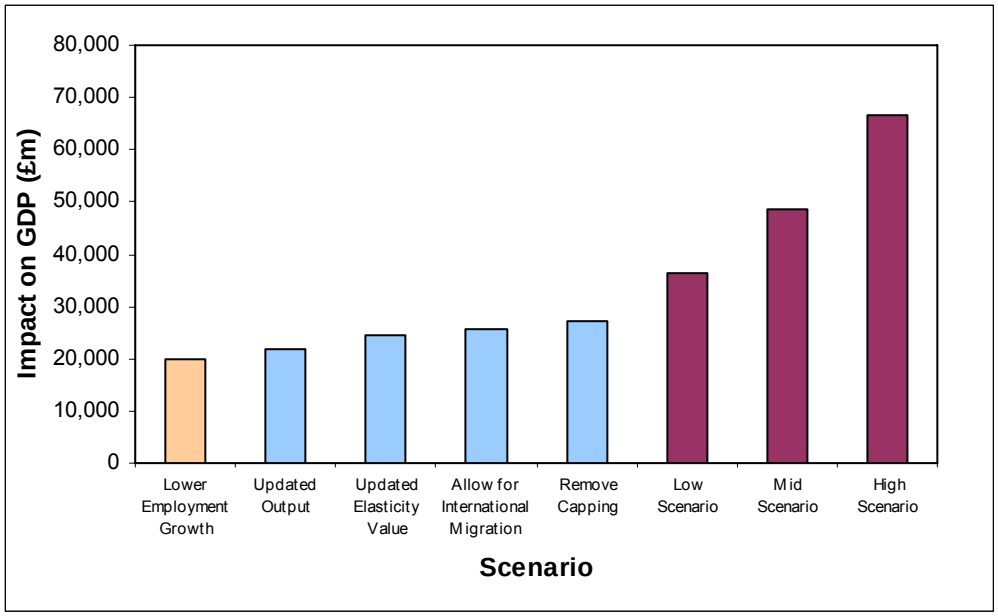


Figure 8.1: Scale of Agglomeration Benefits

Appendix A – Select Link Based Crowding Function

The data used is Crossrail's select link analysis post distribution and mode split (DMS). This gives us the unconstrained trip demand in 2016 both with and without Crossrail for the peak period, split by levels of crowding. This is shown in table A1 below. The question that then needs answering is how much of this unconstrained demand will actually be met, or more precisely, how many people will be deterred from taking up employment in Central London, in order to prevent experiencing the levels of crowding?

Table A1: Unconstrained trip demand in 2016 with and without Crossrail

With XR	Total	0.0-0.3	0.3-0.75	0.75-0.8	0.8-1.0	1.0-1.25	1.25-1.5	SL>1.5
Dogs	37,905	60	784	365	6,155	12,695	8,997	7,069
Central	456,086	241	3,832	6,864	22,186	130,265	153,576	90,283
Without XR								
Dogs	37,905	70	34	5	210	13,441	12,382	9,921
Central	456,086	246	2,941	2,321	12,027	66,434	193,066	128,424

We assume that all of the future trips demanded are attainable on the London transport network, but only in a certain distribution of crowding – ie they cannot all be attained just by subjecting all of the new travellers to the top level of crowding (SL>1.5). Based on 2001 tables, around 15% of peak hour trips made are at the highest level of crowding. We take the view that the distribution of people willing to be subjected to the various levels of crowding will not change substantially. 15% of new users will be willing to travel at the highest level of crowding. This assumption relies on the proposition that the proportion of jobs offering high enough rewards to make people believe it is worthwhile experiencing the levels of crowding will remain roughly constant. We believe this is not unrealistic.

Using the 2001 tables we therefore calculate a distribution showing what proportions of people are willing to experience the various levels of crowding. The result is shown in table A2.

Table A2: Distribution of attainable levels of crowding

	0.0-0.3	0.3-0.75	0.75-0.8	0.8-1.0	1.0-1.25	1.25-1.5	SL > 1.5
Dogs	0.1%	9.4%	1.8%	11.1%	30.6%	28.3%	14.1%
Central	0.0%	0.8%	0.6%	8.3%	26.6%	36.7%	15.9%

This distribution is then translated into actual trip numbers split by levels of crowding. This results in an 'attainable' split of trips. This is shown in table A3 below.

Table A3: 'Attainable' 2016 trip distribution

	Total	0.0-0.3	0.3-0.75	0.75-0.8	0.8-1.0	1.0-1.25	1.25-1.5	SL>1.5
Dogs	37,905	25	3,552	677	4,194	11,599	10,744	5,335
Central	456,086	167	3,453	2,742	37,935	121,512	167,583	72,692

The next step is to compare the unconstrained trip demand with the attainable levels. A very extreme way to do this would be say that anything exceeding the attainable levels is not attainable – ie all of the people over and above the 15% willing to experience the highest levels of crowding are completely deterred from travelling.

However, examining a bar chart of these numbers (shown in Figures A1 and A2) we see that the overall distribution of crowding levels changes dramatically. For example, in both the Isle of Dogs and Central cordons, the 'with Crossrail' scenario shows the trips subjected to the highest level of crowding increasing and those experiencing the second highest level falling below the attainable level. It is not realistic to say that all of the excess people at the highest level of crowding will be deterred when there is effectively 'spare capacity' at the '1.25-1.5' level.

For this reason, we have considered a 'crowding conversion factor'. This allows for the fact that if a certain number of people are deterred from making trips due to the high levels of crowding they would experience, they will actually make the journey more pleasant (less crowded) for some of the remaining passengers. The net effect being that not all of the 'deterred' trips are unattainable as some will be 'transferred' into the lower crowding category. Depending on the number of people experiencing the lower levels of crowding to which travellers are 'transferred' these people may still be deterred, but not always.

For example in the Central cordon, the 'without Crossrail' scenario shows that a large number of people at both the 'SL > 1.5' and '1.25-1.5' levels of crowding will be deterred (as demand is greater than the attainable level) but that the '1.0-1.25' category has a large amount of spare capacity. Thus a proportion of the deterred people in the higher two groups will still make their trips but will experience lower levels of crowding due to the fact that some people were deterred from travelling.

We take a view that this crowding transfer occurs down the different levels of crowding until the bottom three categories '0.00-0.3' to '0.75-0.8' as once these low levels of crowding are reached, everyone is willing to travel and thus people are no longer deterred.

The method by which the unconstrained trip demand tables are calculated is extremely complex, taking into account every different interchange on the London transport network, and thus it is impossible to come up with a completely accurate way of measuring the level of transfer down the crowding zones. However we simplify the problem by creating a 'crowding conversion factor'. This factor represents the proportion of unattainable trips which are transferred down to the lower level of crowding. For example a value of 0.8 would be saying that 20% of the unattainable trips would be deterred and 80% would be transferred to the lower level of crowding.

Figure A1: Bar chart comparing unconstrained and constrained (attainable) trip demand into the Isle of Dogs Cordon in 2016 for different maximum levels of crowding

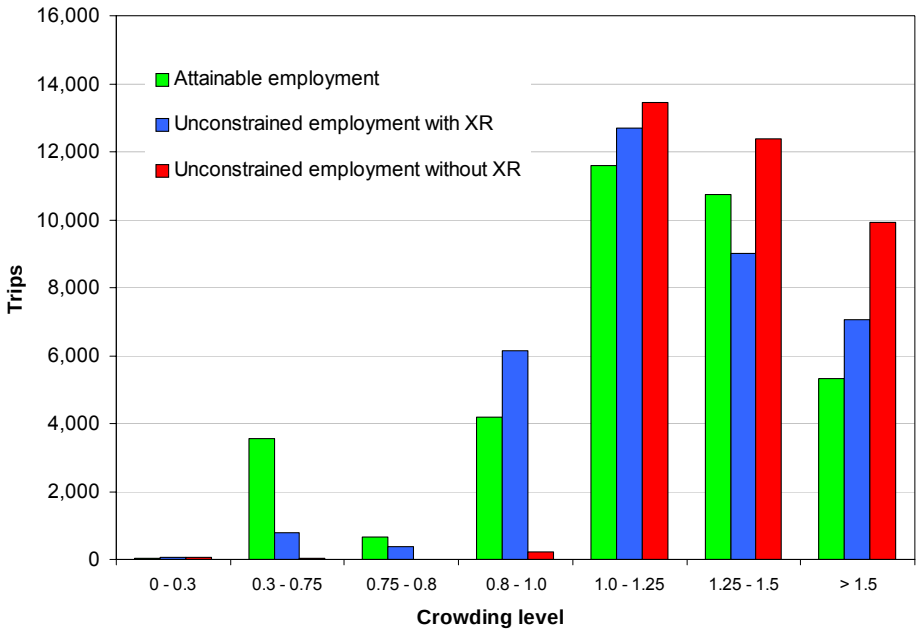
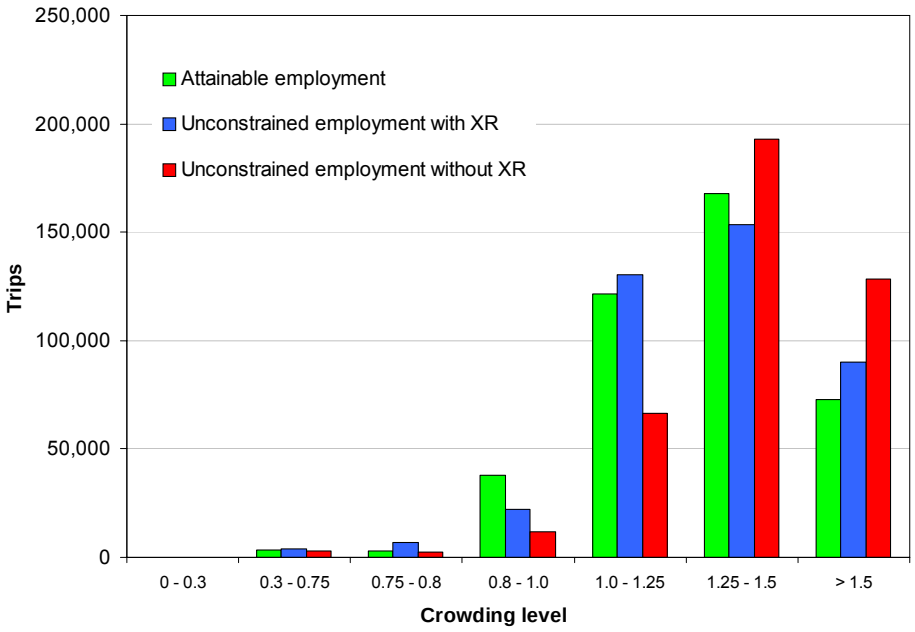


Figure A2: Bar chart comparing unconstrained and constrained (attainable) trip demand into the Central Cordon in 2016 for different maximum levels of crowding



We believe this method encompasses two stylised facts which have become evident from our previous work:

1. People are deterred from travelling by increases in levels of crowding that they will experience
2. People are attracted to travel by low levels of crowding, or reductions in the crowding they will experience

The crowding conversion factor thus effectively allows for effect number one to occur, followed by effect number two. The overall net outcome being that a proportion of trips in excess of the attainable level are fully deterred from travelling resulting in a proportion of people who would previously have been deterred actually experiencing a lower level of crowding and thus still choosing to make the trip.

We consider a range of values for the 'crowding conversion factor' (Ç) and compare the results in order to gauge what might be a realistic assumption to make. First we consider the extremes, if we take Ç = 1, we allow all trips to be made, this effectively just moves people from the highest levels of crowding to the lower levels. This is completely unrealistic. If we take Ç = 0, we deter all trips above the attainable levels, the results of this are set out in table A4 below.

Table A4: Trips deterred with Ç = 0

Cordon	With XR	Without XR	Difference
Dogs	4,792	8,067	3,275
Central	26,343	81,215	54,871

The total trip increases from 2001 to 2016 are only 20,074 and 58,191 for the Isle of Dogs and Central cordons respectively. These tables enable us to qualify how unrealistic this extreme assumption really is. It is saying that without Crossrail, not only will all of the future demanded trips be deterred, but some of the existing ones will too. This is simply not going to be the case. Thus this gives us an idea of what might be a realistic value to take for the crowding conversion factor. Considering a range of values, we conclude that the factor should be somewhere within the range 0.8 to 0.9. The results for these factors are set out below.

Table A5: Trips deterred with Ç = 0.8

Cordon	With XR	Without XR	Difference
Dogs	1,134	3,373	2,240
Central	5,292	25,355	20,063

Table A6: Trips deterred with Ç = 0.9

Cordon	With XR	Without XR	Difference
Dogs	578	1,973	1,395
Central	2,981	14,437	11,456

Based on this style of analysis we therefore conclude that a realistic range for the number of trips deterred due to not building Crossrail lies between 1,500 and 2,000 in the Isle of Dogs and 11,500 and 20,000 in the Central cordon.

For the purposes of the analysis in this report we simple consider one Select Link based scenario, taking the Crowding Conversion Factor equal to 0.9, on the basis that this is at the most end conservative end of our identified range of values.

Appendix B - Cordon Based Crowding Function

The Cordon Based crowding deterrence function used in the report is based upon previous work by Colin Buchanan and Volterra examining the relationship between crowding on the underground and the inclination of new passengers to travel on the trains. Four underground lines were studied[18] with data detailing passenger demands and train capacities recorded on the links between all the stations in both directions.

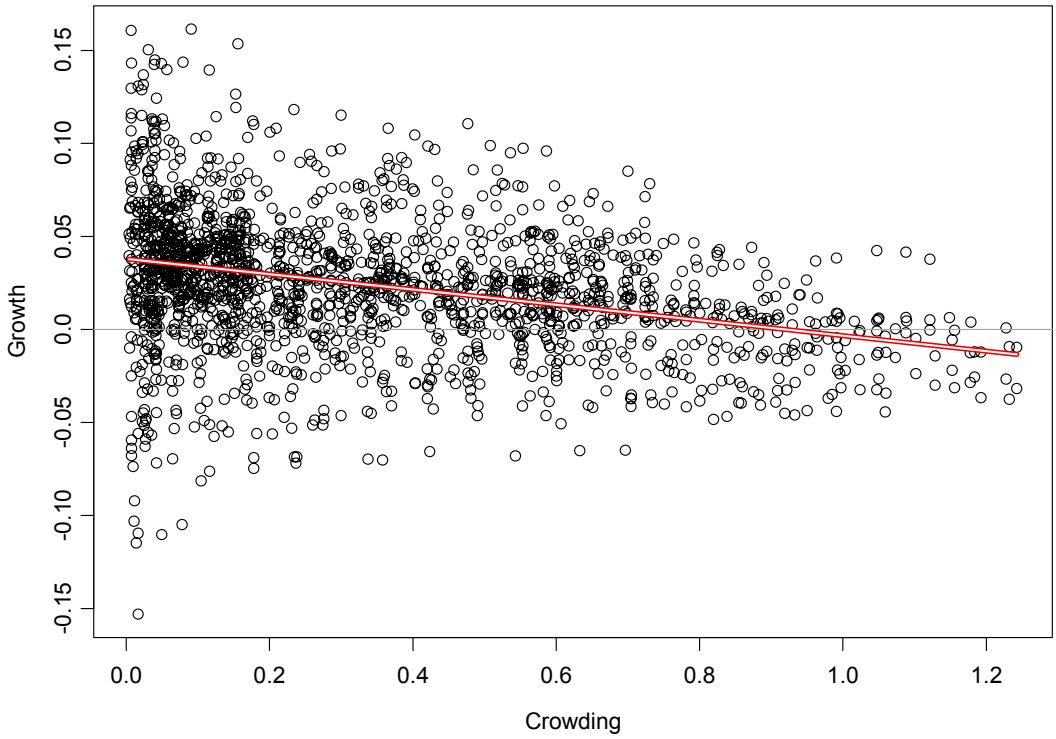
Data used: Passenger demand and capacity on 314 underground links, recorded in 1981, 1987, 1994 and 2000.

Extrapolated data: Crowding = demand/capacity
Growth = [demand(ti)/demand(ti-1)](1/# years) -1

Figure B1 plots the extrapolated crowding against the passenger demand growth. Growth has been calculated over all possible periods (of which there are six), with the corresponding crowding coming from the start of the period. In this way we cover periods where there was net total demand increases as well as decreases.

Figure B1: Passenger crowding against demand growth for all time periods

Thick line indicates linear least squares regression



Overlaid on this plot is a least squares linear regression fit. A summary of this regression is given in figure B2. We can see here that the coefficient of crowding is equal to -0.038. This means that for an increase of crowding of 0.1, passenger demand growth falls by around 0.4%. The corresponding p-value here is zero, telling us that this is a highly significant relationship.

[18] Piccadilly, Victoria, Central and Northern Line

Figure B2: Linear regression of growth on crowding, all time periods

Call: lm(formula = growth ~ crowd, data = all.points)

Residuals:

Min	1Q	Median	3Q	Max
-0.1888	-0.01808	0.001292	0.01752	0.1286

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	0.0363	0.0012	29.7096	0.0000
crowd	-0.0383	0.0027	-13.9657	0.0000

Residual standard error: 0.03483 on 1880 degrees of freedom

Multiple R-Squared: 0.09399

F-statistic: 195 on 1 and 1880 degrees of freedom, the p-value is 0

The suggestion is that people are deterred from travelling from increases in crowding even at very low levels. The other way to look at this is that people are attracted to travel on trains with low levels of crowding.

Next we test for non-linearity in the relationship by fitting a local regression. The fitted curve from this technique can be seen in figure B3. When we fit local regression we can specify a parameter known as the span, which specifies the amount of data that is considered at each point of the regression to estimate the fitted curve. Having tried different span parameters we find that a value of 0.25 provides the best non-linear fit for this data.

The local regression reveals a slightly different trend to the linear. We can see growth falling relatively sharply for crowding between 0 and 0.2. Between 0.2 and around 0.6 growth is fairly flat. From 0.65 onwards the curve starts to fall again, crossing zero growth at around 0.9. The implication is that for crowding above 0.9 average growth becomes negative.

We can test to see if this regression is a significant improvement on the linear fit by using analysis of variance (ANOVA). Figure C4 shows the ANOVA table, comparing the local and linear regressions. The p-value obtained is 0.025, which is significant at the conventionally used 5 per cent threshold, telling us that the local regression is an improvement on the linear regression.

Figure B3: Passenger crowding against demand growth for all time periods

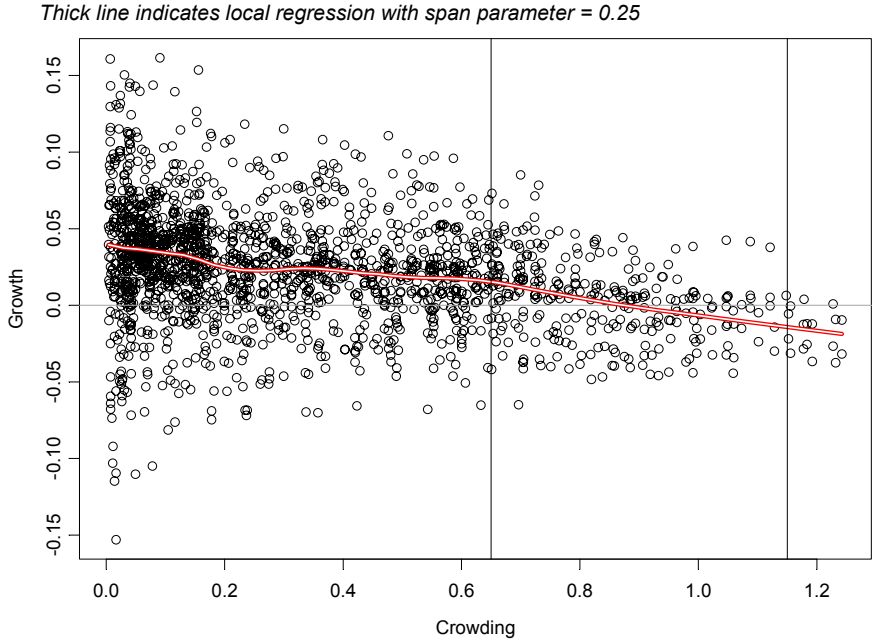


Figure B4: ANOVA for local regression with span=0.25 against linear fit

Model 1:

loess(formula = growth ~ crowd, data = all.points, span = 10, degree = 1)

Model 2:

loess(formula = growth ~ crowd, data = all.points, span = 0.25, degree = 1)

Analysis of Variance Table

	ENP	*RSS*	*Test*	*F Value*	*Pr(F)*
1	*2.0*	*2.2805*	*1 vs 2*	*2.22*	*0.025295*
2	*7.4*	*2.2587*			

One of the key issues in relating crowding and growth on the these underground links to crowding and deterrence across the central cordon in total is deciding whether or not we are talking about comparable levels of crowding. We conclude that we are on the basis of the following:

- Demands and capacities in both circumstances are measured during the peak 3 hour period
- Capacities are both measured in terms of Planning Guidance Capacity (PGC)
- The levels of crowding on links across central cordon are all relatively high. Average crowding in 2001 was 0.75, but only 5 of the 50 links were below 0.5. The possibility of people 'spreading' in order to accommodate growth is minimised.

One of the remaining issues is that the cordon data includes both main-line and DLR trains. Without further evidence there seems no reason why these trains should behave differently in terms of their crowding deterrence, especially as crowding has been measured in the same way.

Having decided that crowding in the underground link analysis can be compared to average cordon crowding we now build our crowding deterrence function.

Looking back again at figure B3, there is clearly a negative relationship in early stages, as well as the later, with a less strong relationship between. We conclude that the below crowding of 0.2 people are actually attracted to travel, above the natural growth rate. Between 0.2 and 0.65 there is relatively little deterrence effect. Above 0.65 crowding starts to become a deterrence.

Although average growth flips to being negative for crowding levels at around 0.9, it is worth remembering that included in this analysis is the period 1987 to 1994, over which total trip demand dropped. Also, there exists links with high crowding and high growth, for example Liverpool Street to Bank had crowding of 1.12 in 1981, but still saw annual growth of 3.7 per cent between 1981 and 1987.

On the basis of this information, our crowding function works in the following way:

Figure B5: Crowding deterrence function

Crowding C Deterrence

$\boldsymbol{C} < 0.65$ *No deterrence*

$0.65 \leq \boldsymbol{C} < 1.15$ *Proportion of people deterred* $= (\boldsymbol{C} - 0.65) / (1.15 - 0.65)$

$\boldsymbol{C} \geq 1.15$ *All deterred*

We choose 0.65 as the threshold for crowding deterrence to start. 1.15 is taken to be the absolute upper limit on crowding, on the basis of the most extreme observation above. Between these limits, the number of new travellers who are deterred is proportional to the position of the level of crowding between the limits. For example, at crowding of 0.9, half way between the limits, half of new travellers will be deterred. Above 1.15, all new travellers are deterred.

We evaluate the crowding function annually, using our unconstrained employment forecasts along with cordon crowding levels as inputs. The process works as follows:

1) Crowding in year n is calculated
2) Unconstrained trip demand for year n+1 is calculated
3) The number of people who are deterred in year n+1 is calculated
4) The total number of people making trips, and consequently the crowding in year n+1 is calculated
5) Proceed to next year and repeat the process